HOSTED BY unisel UNIVERSITI SELANGOR

Selangor Science &Technology Review
Special Issue: Science and Technology for Society
Vol 5 No 5 (2021)

Exploring Aesthetic Values in Product Design Skill For TVET Programs Through Computer Aided Design Module

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Abstract: In the era of globalization, product design innovation is essential in daily human life. Innovation is imperative to the advancement of society, especially towards the need for problem-solving. This relation has seen the expansion of design innovation in the education sector increase tremendously over the past years. Computer-Aided Design (CAD) is a significant subject in the Technical and Vocational Education and Training (TVET) program for product design creation. It is an important module that helps the younger generation to become more innovative.Nonetheless, the dependency on technology has seen drastic changes towards product creations. It is noticeable to see the lack of aesthetic valuing applied in creating design via CAD module. After that, it translated into the shortcoming in the final design outcomes. Despite the increasing dependency on CAD software, the conventional design process must always be systematic and aesthetically objectified. This study aims to find suitable aesthetic value factors adapted into the CAD learning program. A literature study was conducted by reviewing various articles and publications related to aesthetical context and product design skills. The result shows four main factors and nine sub-factors. They are product design requirement (functional value and social value), product design concept (form and colour), product design detailing (texture and material), and product design evaluation (safety, ergonomic and emotional value). The study also explores and develops a theoretical framework for teaching and learning the CAD module.

Keywords: Product design skills, TVET, CAD, Aesthetic

1. Introduction

Product design and its development have been on an accelerating tendency of late. The rapid pace of technological advancement was the primary contributor to this happenings. Though globally affected, the product design process will always be limited to the domestic market. Therefore, the product design needs to go through a systematic and carefully planned approach to ensure that each product design meets the criteria and standards requirement (Baxter, 2017). In systematic planning, the design process must indicate a flow of standard operating procedures that covers relevant developmental phases. Fauzi (2017) mentioned that the design process should have characteristics such as ergonomic, color, form, function, safety and follow the user's needs for trends and tendencies. Novoa (2018) added that in doing so, it will create the opportunity for the manufacturing companies not just to gain income or profit but also conduct sociology studies and demographic research among the users and introduce new technology to them. This flow of processes and considerations will influence the levels of innovations of any products design.

Innovation is critical in creating new opportunities to generate higher value for society socially and economically (Usman et al., 2016). Making changes is an essential element in the national development plan because it can increase productivity and competitiveness to become a developed country (Chang & Taylor, 2016). The government has made several

efforts to enhance Malaysia's international position in innovation and competitiveness. Some initiatives are to create an educational program that can produce qualified and competent human capital in adhering to the IR4.0. The students are the human capital that needs to expose to IR4.0 knowledge due to achieve with other developed countries (Baxter, 2017).

The Ministry of Education (MOE) has developed vocational and technical programs (TVET), focusing on innovative industry and manufacturing. One of the programs related to product design is the Industrial Machinery program. At the same time, another is technology in applying computer-aided design (CAD), which has become an essential module for the programs. CAD is the key to successful product development, as it helps companies analyze the design, identify deficiencies, and optimize the manufacturing of the product.

The beginning stage of product development is the most critical. It starts with the agreement of the product requirement. Next, develop strategy and initial idea into a functional prototype. This process signified how CAD could play a pivotal role in ensuring the product design process runs smoothly and avoids future problems.

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2. Statement of Problem

The Vocational Education and Training (TVET) areas of study include engineering, design, food and beverages, and management. The Industrial Machinery course is one of the engineering areas. The students are required to design products for their final projects. Nonetheless, the technical students' performance analysis has shown moderate and low-level performance where the students are relatively weak and lack exposure to aesthetic value in product design (Doran & Ryan, 2017). In general, designing a product is a human-centered approach in terms of strategies, processes, and methodologies in which new product development occurs, business advances, and integration with human needs (Dyer, 2019). Therefore, the production must be of good quality and have high functionality. Yet, there are weaknesses in creating a quality design that still occurs, especially on aesthetic values (Yehua et al., 2018).

In addition to the TVET colleges, similar issues happen in other higher education institutions. According to B. Saleh (2020), many product designs produced by design technology students in the Institute of Teacher Education (IPG) do not show maturity in terms of the appearance and packaging of the final product. It is also an issue facing engineering students, as stated by Syukri et al. (2017), though the context of physical aesthetic values might be unfamiliar elements to their practice. Therefore, this study needs to combine the creative and the technical aspects into creating a final product design.

2.1 Purpose of study

This study explores aesthetic content framework skills in the CAD module and recommends it to the Industrial Machining Technology conducted under the TVET program. The aesthetic values factors in the product design skills will provide information that could guide and support material for instructors' teaching and learning process.

2.2 Aesthetic in product design skills

Aesthetic value in design artwork is essential in ensuring that every outcome produced is of high quality. The concept of aesthetics or beauty of a product usually depends on several complementary elements such as finesse, skill, design, function, and appearance. The idea of beauty in the aesthetic sense is satisfaction through the art expression. The

concept of aesthetics is commonly associated with two approaches to art appreciation. The first is the desire to examine the element of beauty found in an object or image in work. Some writers describe the beauty of art objects seen based on formalistic aspects. Second, it involves expressing feelings or emotions that arise because of the experience of beauty through the appreciation of art. Feelings or emotions affect an art admirer's interpretation of the meaning of iconography.

Product design development is increasingly important to attract consumers to own each product designed (H. Lee & Lee, 2017). However, it needs to be attractive and quality, such as ergonomics, color, form, function, and safety, significantly affecting consumer selection. Product design quality also involves consumers' views, which is essential, especially in developing new products. It shows that the right quality product will address the consumer needs and demand.

Customers will always expose to better options in the market. Therefore, product quality becomes an essential requirement (Y. L. Lee et al., 2016). As mentioned by Efer (2017), customers will look at aesthetics (parts and component shapes), product colors (tones, contrast, and reflection), and materials (product texture, surface, and weight) needed in the product design development process. Hence, the involvement of consumers in determining the marketability of products in the market becomes essential. It indicates that the role of consumers in deciding product design needs and properties is necessary.

Moreover, the aesthetic of the product design is about the neatness, physical beauty of the product, usability, comfort, and safety (Mohammad et al., 2016). In determining the quality aspects that must be present in the design of a product, the researcher only focuses on four elements that are appropriate to the study that the researcher conducts, namely from the aspects of (i) form (ii) color (iii) ergonomic (iv) material (v) safety and (vi) consumer behavior. Justification for selecting all six aesthetic elements of product design skills fits with the CAD before the prototype-making process (Shahriman, 2020; Ulrich & Eppinger, 2016).

2.3 Pahl and Beitz Design Model

In the mid-1980s, Pahl and Beitz introduced a comprehensive design model (Pahl & Beitz 2013). lthough they do not follow the exact sequence of actions, their methodology still follows the necessary design process. Pahl and Beitz design methodologies represent four main phases beginning with (1) task planning and explanation, (2) conceptual design, (3) realization/embodiment design, and (4) detailed design.

Task explanations involve the collection of information about the problem under consideration. The conceptual phase consists of establishing a functional structure, finding appropriate solution principles, and their combination with the variations of concepts. In the realization and embodiment design phase, the detailed design focuses on arrangement, shape, dimensions, surface appearance, tolerance, and material specifications in technical and economic aspects.

Pahl, G. & Beitz, (2013)) further explain that their methods may require a repetition process to achieve the best results that lead designers to create robust solutions. This model follows the market positioning methodology, which means that the first step is to study the socio-economic factors of the market and compare them with the design and development potential of industrial or company products. Through the results gathered, the design team can systematically find new product ideas compatible with the company's development team and manufacturing capabilities. This model starts with the primary planning and explanation to produce a quality design that needs to be well thought out.

2.4 French Design Process Model

The design process model pioneered by French (1971) was developed to develop the system and product design. There are seven main components focused on the product development process: the needs, analysis of the problem, clarifying the problem statement, applying conceptual design, embodiment, scheme selection, detailing, and working drawings.

The French Design Process Model selection as one of the backup models in this study is its strength in producing quality product design. This model explains that evaluation activities need to be present at every stage of the design process. Each item presented is given significant emphasis and considered as design information to be developed. This model explains that each product design-developed method will go orderly and systematic. Therefore, the outcome of the product design meets the set standards such as ease of use, safety compliance, aesthetic, ergonomic features, and user interest. Coinciding with the dimensional positioning of the design models, The French Design Process Model is a design work reporting procedure that supports best design practices with systematic design process designation (Wynn & Clarkson, 2018).

3. Research Methodology

The researcher conducted a literature analysis to determine the aesthetic elements influencing successful product design skills implementation. The reference material obtained is via electronic reference through websites and journals in databases such as Proquest, Emerald, ScienceDirect, MyCite, Scopus, ISI Web of Science (WoS), books, and reports published by relevant agencies. Below is figure 1 to show the flow charts of the literature review.

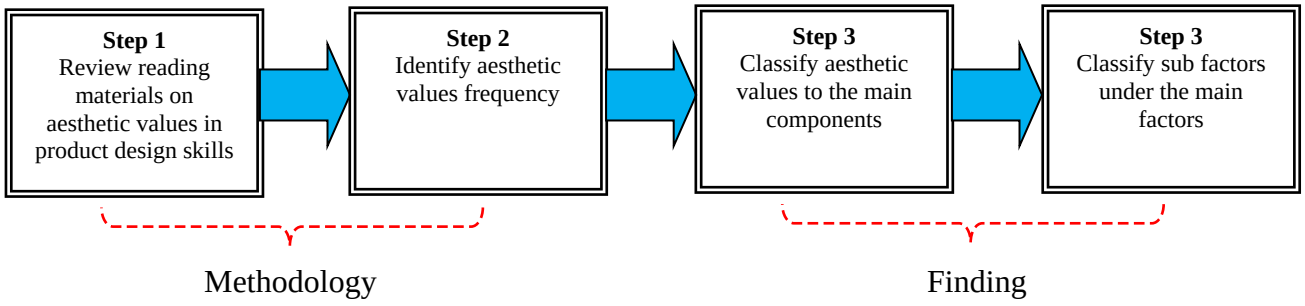

Fig. 1. Flow charts of literature review

4. Findings

The reading materials found that many researchers have identified important factors to implement aesthetic value in product design skills based on literature reviewing methods. The study highlights that Pahl and Beitz Design Model and French Model have similarities in product design skills. Both models emphasize Product Design Requirements, Product Design Concepts, Product Design Detailing, and Product Design Evaluation as the main components.

The literature analysis concluded that four main factors and nine sub-factors (as seen in Figure 2) were critical success factors in successful product design skills.

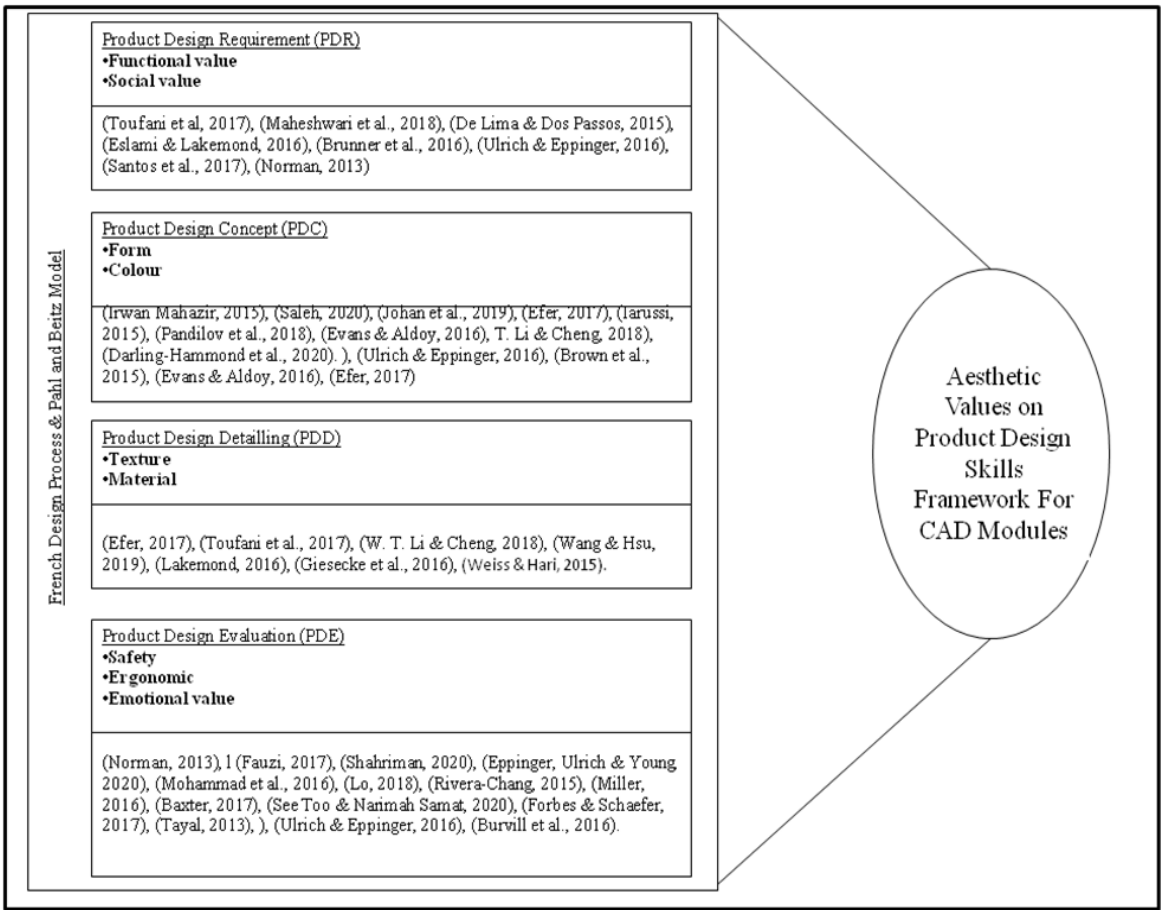

Fig.2. Literature review analysis

4.1 Product Design Requirement

Product design requirements (PDR) are intended to develop and determine logical and identified needs to explore and develop a complete perspective of the problem. Product design requirements are a study conducted to identify problems by collecting data, interpreting data, and organizing needs according to the importance of the product. Preliminary studies related to product design can obtain consumer feedback from products marketed to know consumers' tastes and needs (Eslami & Lakemond, 2016). Initial research to identify design needs to highlight new products is one of the preliminary research tasks borne by design. Preliminary studies are applied to ensure the designer understands the situation and problem.

Every designer's job is to produce the product design, but the search for information related to the product to be made comes from the users who use the product (Brunner et al., 2016). The information obtained is collected and analyzed through a project summary. The summary of this project is a statement of problems posed through the findings of the report by users (Chua et al., 2020).

A study conducted by Mithas, Ramasubbu, and Sambamurthy (2011) on 80 firms in various manufacturing and service industries shows that significant information management capabilities are through user feedback and perspectives. Identifying compelling user needs such as collecting raw data from users, interpreting raw data in user needs, organizing needs follow the hierarchy of product importance (Ulrich & Eppinger, 2016). Developing a new product design is risky if the information related to the product is inaccurate. The collection of data or metadata from customers is very beneficial for producing quality products. In conclusion, PDR was involved with consumer behavior which the consumer will look for the functional value and social value.

4.1.1 Functional Value

Consumers evaluate if the product works well and if it will benefit them. Consumers also look for the usability and safety of the products. For example, they test if using the products gives them comfort. According to Toufani et al. (2017), consumers love durable products, reliability, ease of use, and usefulness. A durable product means it is of long-term use. Reliability means the product function continues working long hours.

Meanwhile, the word terms reliable means that the consumer can get spare parts for repair or upgrade the products. Ease to use is to describe how easy the consumer uses the product. For example, consumers must tap Find within 3 seconds of accessing the mobile phone interface (Maheshwari et al., 2018). Usefulness is about the designer applying the usefulness requirement to every design aspect (Wang & Hsu, 2019). Therefore, it represents a goal-oriented, rational, and functional purchase when an individual uses a new product.

4.1.2 Social value

Hoo Na et al. (2017) defined using new products as "utilities that are perceived to originate alternative association with one or more specific social groups. It suggests that consumers will be confident in using a new product when they see others also using it. It manifests self-confidence based on general appraisal perceptions of the product (Norman, 2013) and a belief in improving community life. Consequently, it proves that witnessing other users can affect consumers' perception of using a new product.

4.2 Product Design Concept

The Product Design Concept (PDC) is a complete framework in developing the final design and evaluating the product's effectiveness (Otto & Mandorli, 2018). The development will meet the objectives of the design process. The methods include creating brief descriptions, flow charts, sketches, modeling, calculations, and a few more to translate design ideas and concepts (Lars B Ollen, 2015). The chosen design concept must contain detailed information to prove its functionality. The importance of this design concept is to obtain the product data. Ullman (2015) mentioned that 15% of the time, the overall design process is used by most companies and industries in the United States to produce the product design concept. The idea of product design is also an activity of generating ideas by designers and simultaneously solving design problems that meet consumers' needs and the market (Beasley, Piegl, & Rosen, 2018; Ulrich & Eppinger, 2016). The generation of ideas can feature various creative and innovative design products (W. T. Li & Cheng, 2018).

Commonly the concept ideas needed has to be produced in large numbers: at least four concepts that can strengthen the product design objectives. It indicates the importance of choosing the best concept to implement after analyzing several ideas unearthed by the designer. Subsequent, designers and design engineers will refine the drawing ideas to get results with the best engineering features and appearance (W. T. Li & Cheng, 2018). At the initial stage, to translate the basic ideas and principles of a product, designers can generally use models, plans, and sketches to produce concepts that have been identified (Ullman, 2015; Ulrich & Eppinger, 2016).

Among the three methods, sketching is the most efficient method for producing faster (time factor) and cheaper materials (cost factor) than models and plans. Ideas communicated with high-quality sketches are more creative than similar ideas with low-quality illustrations (Ranscombe & Bissett-Johnson, 2016). This method also gives the advantage of comparing sketches produced by different designers. Sketches are also identified as one of the most effective mediums when combined with other mediums, such as oral explanations and hand gestures (Darling-Hammond et al., 2020). In conclusion, PDC is an idea to develop the final design. The implementation of design concepts can apply in various ways, such as brief descriptions, flow charts, sketches, and modeling to translate design ideas. It highlighted the importance of form and colour in the ideation drawing.

4.2.1 Form

The term 'form' means defining space, creating contrast, and visually adding volume to a composition. The structure is about composition line, shading, and others become one three-dimensional drawing (Lo, 2018). Form greatly influences design because it is significantly related to appearance in 3D format (Kang et al., 2019). If the form drawing or shape is not attractive, automatically, the product has no aesthetic value (Haug, 2016). Therefore, it will look incomplete or not solid or impossible to make in a manufacturing plant. A good form is a balanced shape such as symmetry or two parts (Mechner, 2018). The form drawing should have line and space and follow the use function and correlate with the color (Efer, 2017).

4.2.2 Colour

The use of colour in product design has a role in highlighting the beauty of a product. Without paint, the product will not be perfect and will show dimness. Colour also affects the

development of the products. Colour can influence the product market and is a necessary element in designing a product. The purpose of the colour application is to create the mood or mood of the user. Also, the product's colour will explain the function (Irwan Mahazir, 2015; Saleh, 2020). Colour also has a significant effect on human life and gives visual impacts. Colour through the visual senses provides a degree of difference over to individuals' mental and physical perceptions (Johan et al., 2019).

It shows that the visual outcome may affect product marketing and customer desire to purchase (Efer, 2017). The process of design, appearance, style and colour presentation of a product will ultimately highlight the effectiveness of colour plan implementation and colour design optimization (Iarussi, 2015). These design aspects can help in the decision-making process and increase the acceptance of product offerings. Therefore, the surface used in the colour design should also consider the design principles of the product colour arrangement and the purpose of using a product (Pandilov et al., 2018).

Computer-Aided Design (CAD) in 3D can automatically choose the use of colour design and a series of colours by professional designers and can finalize their colour design suggestions more efficiently. 3D CAD can automatically select product color design and complete color design proposals more efficiently on any product (Evans & Aldoy, 2016). At the same time, the time required to produce a colour scheme by CAD is shorter than using a traditional process (Booth et al., 2016).

4.3 Product Design Detailing

Product Design Detailing (PDD) means the complete external and internal description through visuals and data (Glen Truman, 2016). It will provide information on each part's arrangement, shape, dimensions, tolerances, surface properties, materials, and industrial processes (Ullman, 2015; Gracia-Ibáñez & Vergara, 2016a). It will show the specification of the product. Therefore, the supplier quickly provides each design part. It must be involved with detailed engineering drawings suitable for the manufacturing industry. Then, pictures and installation instructions are also specified. Detailed design includes construction and testing of several production versions of the product.

In conclusion, PDD is a detailed design component of the product. Computer-generated drawings include the three-dimensional solid models involving the surface or texture and retain the material. The elements found in the product design detailing components are three-dimensional (3D) modeling and product detail design drawings that illustrate the product assembly.

4.3.1 Texture

One path to enhanced product design involves manipulating detailed surface textures that affect product performance and aesthetics (Efer, 2017). The texture is a surface quality related closely to our sense of touch or sight due to appeal to the senses and makes us feel (Toufani et al., 2017). All the things we see around us think or differentiate for a specific product section—for example, a button switch for electronic products (Ranscombe & Bissett-Johnson, 2016). Texture may be hard to soft or smooth to rough. Textures to show the smooth and pleasant surface draws us to them; other abrasive textures are unpleasant and repelling to the sense of touch but perhaps not visually (W. T. Li & Cheng, 2018; Wang & Hsu, 2019). In the end, a designer needs to use suitable materials for the product.

4.3.2 Material

Material is an element that needs to be studied by the designer. It affects the appearance and shelf life of use (Souza et al., 2017). In the influence of the product appearance, suitable materials can produce tactile on the product for human comfort (Eslami & Lakemond, 2016). However, selecting appropriate materials is significant because it also affects the cost of production, safety, and recycling (Jaafar et al., 2018; Usman et al., 2016; Wang & Hsu, 2019).The selection of appropriate materials will impact a product's perceived value and sustainable value (Souza et al., 2017). It has to do with consumers who want durable, quality, environmentally friendly, and have safety features. In comparison, the manufacturer and designer will look at production costs materials (Iqbal et al., 2020; Tsegaw et al., 2017).

4.4 Product Design Evaluation

The Product Design Evaluation (PDE) is an evaluation method performed by observing and evaluating the designer's skills in producing a product design and determining product quality. The object of product evaluation is the quality of the product design created and the designer's skills (in this study are focusing on the students), which is completing the product design. The quality product design competencies in product design skills will be end process with the product design evaluation. Product evaluation is not only on the object of the designed product but also on the process of completing the design and the manufacturing process (Galati et al., 2018). Therefore, product evaluation is also holistic and analytical.

Holistic product design evaluations tend to use an evaluation format that encompasses all aspects of product evaluation. Meanwhile, the analytical review uses several evaluation formats appropriate to the total elements of product evaluation. Assessment from completing product design includes planning, finding information, developing ideas, and designing products. Evaluation of aspects of the product manufacturing process consists of selecting and using materials, tools, techniques, and procedures to produce quality products. Evaluation in terms of product quality includes authenticity, originality, benefits, neatness, beauty, appearance, ergonomics, aesthetics, and product safety (Bernabei et al., 2015; Wynn & Clarkson, 2018).

In conclusion, the PDE evaluation component involves continuous evaluation to determine whether to accept, improve, continue, or complete the product design process. The determination of quality skill in product design will refer to aesthetic, ergonomic, finishing, and safety aspects. It also highlights the context of emotional values by the consumer.

4.4.1 Safety

The safety factor of consumer products is an essential element in the product design to retain customers' attention, thus ensuring demand in the market. Safety is a crucial aspect needed at the beginning and the end of the design process. Security is a priority for all, whether the actual user or even potential consumers. The products that do not meet the protection benchmark set by the agencies involved, such as Standard and Industrial Research Institute of Malaysia (SIRIM), will be blocked from entering the market, thus resulting in a significant loss for the manufacturers. The manufacturers must ensure products are at minimum risk in terms of the probability of accidents and injuries. Two parts of product safety, namely i). safety of shape structure, i.e., the materials used, production quality, and product components, and ii). design safety means the concept presented has high durability and does not cause injury or error in its use.

Design safety means that the concept presented has high durability and does not cause injury or error in its use (Ullman, 2015). Product safety includes protection at the product construction stage involving the use of materials, components, and production quality (Baxter, 2017). The need for detailed design is also significant in product design safety because when there is a change to the product design, it will improve the design details (Love, 2018). Therefore, the manufacturer is responsible for testing to ensure safety and procedures following set standards before marketing their products.

4.4.2 Ergonomic

The concept of ergonomics has been around since 1700. Nowadays, ergonomics plays an essential role in improving the product design creation process (Irwan Mahazir, 2015; Jaafar et al., 2018). Ergonomics is a broad field involving psychology, science, physiology, biomechanical and anthropometric. However, ergonomics generally refers to the satisfaction and comfort of interaction between products and consumers. Ergonomics in product designs are related to the physicality of products and systems or functions (Baxter, 2017; Zainuddin. F, 2017).

Ergonomics, from a scientific perspective, refers to the basics of ergonomic knowledge covering anthropometry, anatomy, biomechanics, engineering, and physical sciences, physiology, psychology, mathematics, statistics, and even management disciplines such as planning, organization, leadership, and control (Fahmi et al., 2015). The word ergonomic comes from the Greek words' Ergos', which means work, and Nomos, which means rules or laws that carry meaning as rules of doing work (Md Isa et al., 2014). At the same time, previous studies conducted by the International Ergonomic Organization define ergonomics as a scientific discipline on the basic understanding of human interaction with specific elements in systems to improve individual and approach performance as a whole in product design processes (Y. Li et al., 2015).

Meanwhile, (Gurkirpal Singh, 2018; Jaafar et al., 2018) explain that ergonomics is a scientific discipline to understand human interaction with systems that use theories, concepts, principles, and methods of designing by optimizing data for human comfort and overall system performance. There are two main objectives of ergonomics: i. improving the efficiency and effectiveness of the design process- one crucial difference between people and machines is that humans make mistakes. In conjunction with that, it can increase the productivity and effectiveness of the system, and ii. Enhance specific humanitarian values in the workplace -– increase security; increase comfort (using technology); reduce operator

fatigue, reduce stress on individuals; increase consumer satisfaction; and improve the quality of life for everyone.

In product design, ergonomics has become essential in developing a product. Ergonomic is about the scientific study of the product's physical, capabilities, and consumer criteria. At the same time, ergonomics is related to the study of consumers with the work environment (Gurkirpal Singh, 2018; Jaafar et al., 2018; Yuhaniz et al., 2018). Technically ergonomics emphasizes the user's comfort while using the product, such as the physical posture of the user, the use of materials, and environmental safety (Merter & Hasırcı, 2018). For example, an office chair design should emphasize physical posture to prevent users from feeling pain, especially in the back of the body. It shows that ergonomics is also closely related to user-friendliness and relevant to human health.

4.4.3 Emotional Value

Emotional value is an essential element when generating ideas for designing human products (Wang & Hsu, 2019). Rationally, consumers will like any products that would solve their daily issues. It shows that the overall product's appearance will also be an essential aspect of consumers purchasing decisions. Meanwhile, the product appearance includes the product concept such as form, texture, color, ergonomic, and service after-sales.

According to Norman (2013), the three levels are visceral, behavioral, and reflective. The visceral level is where consumers think and decide on the product's intention. For example, consumers will believe in product safety. The behavioral level is about the action taken by the consumers after the visceral level, such as consumers purchasing the product after thinking. Meanwhile, the reflective story can happen after consumers have the product and look at the product performance. All three levels show the consumer behavior intends to purchase or look for the new product design.

5. Conclusion

The literature review discussion focuses on the product design process to develop supporting materials in producing product design skills. The literature found that product design requirements, product design concepts, product design detailing, and product design evolution become the primary skills for product design and all involved with the aesthetic. Simultaneously, the product design process includes a systematic approach starting from the brainstorming process, followed by the development process until the production of a product meets the specified specifications and standards. Models and theories adapted in this study have been reviewed and synthesized to propose the research objectives. Thus, focusing on aesthetic knowledge regarding the product design process will help this study. Usually, observing the aesthetic value of the product design skills is the perception of the quality of the material, exciting look, shape, pattern, and lastly, the overall role of design in creating a mood and effect. When examining new product development, the observation of aesthetic value will occur through two experiences, namely logical experience, and aesthetic experience, that will move the individual senses. It means that consumer perception has become essential in product design skills.

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